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TITLE OF THE INVENTION

DISPLAY APPARATUS, METHOD OF CONTROLLING THE SAME, AND  
MULTIDISPLAY SYSTEM

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BACKGROUND OF THE INVENTIONField of the Invention

10 [0001] The present invention relates to an image display device and a method of controlling the same, and more particularly, to an image display device suitable for use in a multidisplay system in which an image is displayed using a plurality of image display devices connected to each other and a method of controlling such an image display device.

15 Description of the Related Art

[0002] Image display devices for use in conjunction with computers or the like and display devices of the dot-matrix type such as liquid crystal displays or plasma displays are widely used. In those display devices, the number of pixels is fixed. Therefore, the resolution (the number of pixels) of an input image signal must be converted to an optimum resolution, depending on the number of pixels of a display device being used.

20 [0003] Fig. 12 is a functional block diagram of a common image display device having the capability of resolution

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conversion. In Fig. 12, reference numeral 100 denotes an image output unit which outputs an image signal, and 200 denotes an image display device. The image display device 200 includes an image input interface 201, a resolution converter 202, a display device driver 203, a controller 204, and a display device 205.

[0004] In this system, an image signal output from the image output unit 100 is input to the image input interface 201 of the image display device 200. If the image signal input from the image output unit 100 is an analog signal, the image input interface 201 converts the input image signal into digital form. On the other hand, in a case in which the image signal input from the image output device 100 is a digital transmission signal according to a digital signal transmission standard such as TMDS, the image input interface 201 outputs the digital signal to the resolution converter 202 via a receiver.

[0005] In a case in which the resolution of the display device 205 is, for example, XGA (1024 × 768 pixels) and the input image signal has a resolution of, for example, SVGA (800 × 600 pixels) lower than the resolution of the display device 205, the resolution converter 202 scales up the number of pixels in the horizontal and vertical directions of the input image signal by a factor of 1.28 thereby generating an image display signal having the same number of

pixels as that of the display device 205.

[0006] Conversely, if the resolution of the input image signal is, for example, UXGA (1600 × 1200) greater than that of the display device 205, the resolution converter 202

5 scales down the number of pixels in the horizontal and vertical directions of the input image signal by a factor of 0.64 thereby generating an image display signal having the same number of pixels as that of the display device 205.

[0007] The controller 204 controls the scaling-up/down process described above. The display device driver 203  
10 displays an image on the display device 205 in accordance with the image display signal generated by the resolution converter 202.

[0008] As is well known, an operating system (OS)  
15 installed on a personal computer has the capability of automatically determining an optimum format in which an image signal is output from the computer to a display connected to the personal computer. This capability is known as the plug and display capability. To achieve the  
20 plug and display capability, an image display device has a memory (such as a memory 206 shown in Fig. 12) in which attribute information associated with displaying is stored, and a computer determines, on the basis of the attribute information, an optimum format in which an image signal is  
25 supplied from the computer to the image display device,

wherein the computer acquires the attribute information by performing DDC (Display Data Channel) communication with the image display device. (DDC is an extended interface standard which allows transmission of information from a display to a host computer thereby making it possible to use a video signal in an extended manner). This attribute information is called EDID information. EDID stands for Extended Display Identification Data and is a specification for transmission of information associated with a display from the display to a host computer. A format in which data is transmitted for the above purpose is defined in EDID. For example, EDID information includes information indicating the resolution of an image display device and the frequencies of horizontal and vertical scanning signals. Thus, if an image display device is formed so as to have the plug and display capability and if the resolution and other necessary information associated with the image display device is described in the EDID information, a computer (image output unit) can determine an optimum format in which an image signal is supplied from the computer to the image display device.

[0009] A multidisplay system is known in the art. In this system, a plurality of image display devices are arranged, for example, in the form of an  $M \times N$  array, and a single image is displayed using those image display devices.

The multidisplay system has advantages that a large screen can be easily achieved, a depth is smaller than that of a single display having a corresponding large screen size, and high brightness can be achieved. Because of the advantages described above, the multidisplay system is used in various applications, such as displays for use in exhibitions or on advertising towers, in which a large-sized display is needed. The technique of displaying an image using a multidisplay system allows for a single high-resolution display device by combining a plurality of low-resolution display devices.

[0010] An example of a multidisplay system is disclosed in Japanese Patent Laid-Open NO. 2000-148080. The multidisplay system disclosed in Japanese Patent Laid-Open NO. 2000-148080 is described below with reference to Fig. 13.

[0011] In Fig. 13, reference numeral 1001 denotes a multidisplay interface circuit serving as a display control apparatus, and reference numeral 1002 denotes a display device. In this figure, suffixes -1, -2, ..., -n following reference numeral 1001 are used to denote similar multidisplay interface circuits, and suffixes -1, -2, ..., -n following reference numeral 1002 are used to denote similar display devices. The multidisplay interface circuit 1001 includes an input data processor 1004, a data output unit, a control data processor 1031 and a control unit.

[0012] The data output unit includes a frame memory write

circuit 1007, a frame memory read circuit 1008, a data selector 1009, frame memories 1010 and 1011, and an up-scaler 1012. The control unit includes a horizontal write start position register 1017, a horizontal write length  
5 register 1018, a vertical write start position register 1019, a vertical write length register 1020, scale-up factor registers 1021 and 1022, a horizontal read position register 1023, a vertical read position register 1024, a horizontal synchronization register 1025, a vertical synchronization  
10 register 1026, an output timing signal generator 1014, a microcomputer 1028, an ID setting circuit 1029 and a data storage memory 1030.

[0013] Image data transferred from the image output unit is written into the frame memory 1010 or 1011 in the data  
15 output unit via the input data processor 1004. In this process of writing the image data, memory areas into which the image data is written is controlled by the horizontal and vertical write start position registers 1017 and 1019 and the horizontal and vertical write length registers 1018  
20 and 1020 in the controller. The image data is read from the frame memory 1010 or 1011 and transferred to the display device 1002 after being scaled up.

[0014] The microcomputer 1028 in the control unit extracts commands contained in control data received via a  
25 control bus, and the microcomputer 1028 transfers data

stored in the data storage memory 1030 into respective registers 1017 to 1026 of the control unit. Those commands specify which parts of the image data should be displayed by the respective display devices 1002-n ( $n = 1, 2, \dots$ ). In  
5 some cases, the command in the control data includes an ID number indicating which one of display interface circuits 1001 in the multidisplay system should execute the command. In this case, the microcomputer 1028 compares the ID number included in the command with an ID number in the ID setting  
10 circuit 1029, and the microcomputer 1028 executes the command if they are identical to each other.

[0015] In the present multidisplay system, as described above, while the same image data is input to all display interface circuits of the multidisplay system, the  
15 respective display interface circuits capture display data of different display areas specified by the control data and display the captured data.

[0016] At present, some personal computers have the capability of outputting a signal with as high a resolution  
20 as QXGA ( $2048 \times 1536$  pixels). Display devices used in conjunction with such high-performance personal computers are needed to have the capability of displaying images with corresponding high resolution.

[0017] In conventional display devices of the dot-matrix  
25 type, even if image signals applied to display devices have

high resolution, images displayed on the display devices are not as high in resolution as the input image signals, because the resolution of display devices is not high enough. One technique for displaying an image having as high  
5 resolution as that of an original signal is to increase the number of pixels of a display device. However, it is expensive to develop such a high-performance display device and a high performance controller for controlling the display device.

10 [0018] One possible technique of solving the above problem is, as disclosed in Japanese Patent Laid-Open NO. 2000-148080, to display an image using a multidisplay system including a plurality of display devices. However, in conventional multidisplay systems, it is necessary to input  
15 a display control signal together with an image signal to respective display devices in order that a correct part of an image is displayed on each display device.

#### SUMMARY OF THE INVENTION

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[0019] In view of the above, it is an object of the present invention to provide an image display device and a method of controlling the same, which make it possible to easily form a multidisplay system.

25 [0020] It is another object of the present invention to

provide a technique of automatically informing a host device of an optimum resolution depending on the layout of image display devices in a multidisplay system.

[0021] It is another object of the present invention to  
5 provide a multidisplay system and a method of displaying an image, capable of displaying an image without a display control signal supplied from an external device.

[0022] To achieve the above objects, the present invention provides an image display device having a display  
10 unit, comprising input/output means for receiving image data from an image display device disposed at an upstream location and transferring it to an image display device disposed at a downstream location, acquisition means for, if the image display device disposed at the downstream location  
15 is connected to the present image display device, acquiring resolution information from the image display device disposed at the downstream location, generation means for generating resolution information on the basis of the resolution information acquired by the acquisition means and  
20 the resolution of the display unit, and first storage means for storing the generated resolution information such that the image display device disposed at the upstream location can acquire the resolution information.

[0023] The present invention also provides method of  
25 displaying an image by controlling an image display device

having a display unit, comprising the steps of inputting  
image data from an image display device disposed at an  
upstream location and outputting the received image data to  
an image display device disposed at a downstream location,  
5 acquiring, if the image display device disposed at the  
downstream location is connected to the present image  
display device, resolution information from the image  
display device disposed at the downstream location,  
generating resolution information on the basis of the  
10 resolution information acquired in the acquisition step and  
the resolution of the display unit, and storing the  
generated resolution information such that the image display  
device disposed at the upstream location can acquire the  
resolution information.

15 [0024] The present invention also provides a display  
control apparatus for controlling an image display device  
having a display unit, comprising input/output means for  
transferring image data received from an image display  
device disposed at an upstream location and transferring it  
20 to an image display device disposed at a downstream location,  
acquisition means for acquiring resolution information  
associated with the image display device disposed at the  
downstream location, generation means for generating  
resolution information on the basis of the resolution  
25 information acquired by the acquisition means and the

resolution of the display unit, and first storage means for storing the generated resolution information such that the image display device disposed at the upstream location can acquire the resolution information.

5 [0025] Further objects, features and advantages of the present invention will become apparent from the following description of the preferred embodiments with reference to the attached drawings.

10 BRIEF DESCRIPTION OF THE DRAWINGS

[0026] Fig. 1 is a block diagram showing an example of a construction of an image display device according to a first embodiment of the present invention.

15 [0027] Fig. 2 is a block diagram showing an example of the detailed structure of a resolution converter according to the first embodiment of the present invention.

[0028] Fig. 3 is a flow chart showing a process of setting attribute information of the image display device according to the first embodiment of the present invention.

20 [0029] Fig. 4 is a diagram showing attribute information of the image display device according to the first embodiment of the present invention.

[0030] Fig. 5 is a flow chart showing a process of  
25 controlling the displaying operation of the image display

device according to the first embodiment of the present invention.

[0031] Fig. 6 is a diagram conceptually showing setting of image signal registers according to the first embodiment of the present invention.

[0032] Fig. 7 is a block diagram showing an example of a construction of an image display device according to a second embodiment of the present invention.

[0033] Fig. 8 is a diagram showing a manner in which image display devices are connected and showing attribute information thereof, according to the second embodiment of the present invention.

[0034] Fig. 9 is a flow chart showing setting of attribute information of the image display device according to the second embodiment.

[0035] Fig. 10 is a flow chart showing a process of controlling the displaying operation of the image display device according to the second embodiment of the present invention.

[0036] Fig. 11 is a diagram conceptually showing setting of image signal registers according to the second embodiment of the present invention.

[0037] Fig. 12 is a block diagram showing an example of a construction of an image display device of a generally used type.

[0038] Fig. 13 is a block diagram showing an example of a construction of an image display device which can be used as a component of a multidisplay system.

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DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0039] The present invention is described in further detail below with reference to preferred embodiments in conjunction with the accompanying drawings.

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First Embodiment

[0040] Fig. 1 is a block diagram showing a construction of an image display device according to a first embodiment of the present invention.

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[0041] In Fig. 1, reference numeral 200 denotes an image display device including a display device 205, an image input interface 201 for inputting image data from an image output unit 100 (hereinafter, referred to as a personal computer), a resolution converter 202 for converting the resolution of the input image data into a resolution optimum for the display device; a display device driver 203 for generating image display signal supplied to the display device, a controller 204 for generally controlling the image display device, a rewritable memory 206 for storing EDID information, a DDC communication processor 207 for

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performing DDC communication with an external device, and an image output interface 208 for outputting image data to the outside. Note that in the present embodiment, two similar image display devices, denoted by reference numeral 200 with  
5 suffixes 1 and 2, are used.

[0042] In the system shown in Fig. 1, image data output from a personal computer 100 is input to an image display device 200 via an image input interface 201. The input image data may be in the form of an analog signal or a  
10 digital signal. In the case in which the input image data is an analog signal, the image input interface 201 includes an analog-to-digital converter for converting the input image signal into digital data at optimum sampling timings and outputting the resultant digital data to the resolution  
15 converter 202. In the case in which the input image data is a digital transmission signal according to a digital signal transmission standard such as TMDS, the image input interface 201 receives the image data using a receiver according to the standard and transfers the received digital  
20 signal to the resolution converter 202.

[0043] The controller 204 detects the resolution of the input image data from horizontal and vertical synchronization signals included in the image data (provided to the image input interface 201).

25 [0044] The resolution converter 202 scales up or down the

input image data so that the resolution of the resultant image data matches the number of pixels of the display device 205. For example, when the number of pixels of the display device 205 is equal to that defined in the SVGA standard (800 × 600) and the resolution (detected by the controller 204) of the input image data is that defined in the VGA standard (640 × 480), the resolution converter 202 scales up the number of pixels in the horizontal and vertical directions of the input image signal by a factor of 1.25 thereby generating an image display signal having the same number of pixels as that of the display device 205. Conversely, if the resolution of the input image signal is, for example, UXGA (1600 × 1200) greater than that of the display device 205, the resolution converter 202 scales down the number of pixels in the horizontal and vertical directions of the input image signal by a factor of 0.5 thereby generating an image display signal having the same number of pixels as that of the display device 205.

[0045] The controller 204 controls the scaling-up/down process performed by the resolution converter 202, detects the resolution of the input image data, and performs a DDC communication process which will be described later. The display device driver 203 displays an image on the display device 205 in accordance with the image display signal generated by the resolution converter 202.

[0046] The image output interface 208 serves to transfer input image data to an image display device at a next stage. The image output interface 208 is formed differently depending on whether the input image data is in the form of an analog signal or a digital signal. In the case in which the input image data is an analog signal, the image output interface 208 buffers the input image data prior to output. If the input image data is a digital signal, the image output interface 208 transfers the digital transmission signal using a transceiver according to a digital transmission standard such as the TMDS standard. Herein, the input signal is directly output.

[0047] Fig. 2 is a block diagram showing an example of a detailed structure of the resolution converter 202. In Fig. 2, reference numeral 301 denotes an image data down-scaling block including a down-scaler 302, a memory write controller 303, and an input timing signal generator 304. Reference numeral 305 denotes a frame memory for storing image data. Reference numeral 306 denotes an image data up-scaling block including a memory read controller 307, an up-scaler 308, and an output timing signal generator 309.

[0048] The resolution converter 202 also includes a horizontal write start position register 401, a horizontal write end position register 402, a vertical write start position register 403, and a vertical write end position

register 404. Which part of the input data should be written into the frame memory 305 is specified by the data stored in those registers. Instead of specifying the horizontal and vertical write end positions by the registers 402 and 404, horizontal and vertical write lengths may be specified by data stored in similar registers.

[0049] The resolution converter 202 also includes a horizontal read start position register 405, a horizontal read end position register 406, a vertical read start position register 407, and a vertical read end position register 408. Which part of the input data should be read from the frame memory 305 is specified by the data stored in those registers. Instead of specifying the horizontal and vertical read end positions by the registers 406 and 408, horizontal and vertical read lengths may be specified by data stored in similar registers.

[0050] Reference numeral 409 denotes a horizontal scale-up/down factor register and 410 denotes a vertical scale-up/down factor register. Data stored in those registers specify the scale-up/down factors by which image data is scaled up/down by the image data down-scaling block 301 and the image data up-scaling block 306. If the scale-up/down factors are set to be equal to 1, the image data is not scaled up/down. Setting of those registers is performed under the control of the controller 204.

[0051] Referring again to Fig. 1, reference numeral 207 denotes a DDC communication processor for performing DDC communication with a personal computer 100 or another image display device 200 connected to the present image display device 200. Reference numeral 206 denotes a rewritable memory for storing attribute information in the form of EDID information according to the VESA (Video Electronics Standard Association) standard.

[0052] Communication between the personal computer 100 and the memory 206 using the DDC communication processor 207 allows the personal computer 100 to acquire EDID information stored in the memory 206 and to output image data in an optimum format to the image display device 200. That is, the so-called plug-and-display capability is achieved.

Furthermore, in the image display device according to the present embodiment, the capability of communication between the controller 204 and the memory 206 makes it possible to rewrite the EDID information stored in the memory.

Furthermore, the capability of communication between the controller 204 and another image display device connected to an input port or an output port of the present image display device 200 makes it possible to supply attribute information between the present image display device and another image display device. In the present embodiment, information associated with the resolution and information associated

with the number of connected image display devices are transmitted via DDC communication. The DDC communication processor 207 is described in further detail below.

[0053] In the present system, as shown in Fig. 1, two similar image display devices (200-1 and 200-2) according to the present embodiment are connected to each other. In the following description with reference to Fig. 3, the operation of only the image display device 200-1 at the first stage is explained unless a description of the operation of the other image display device 200-2 is necessary.

[0054] First, in step S100, attribute information is initialized such that the total number of image display devices  $C_{ti} = 1$ , the number of image display devices at downstream locations  $C_{di} = 0$ , the number of pixels in the horizontal direction  $N_h = N_{h0}$ , and the number of pixels in the vertical direction  $N_v = N_{v0}$ .  $N_{h0}$  and  $N_{v0}$  denote the numbers of pixels each image display device 200 has. In this specific embodiment, it is assumed that  $N_{h0} = 800$  and  $N_{v0} = 600$ . In the next step S101, it is determined whether the image display device 200-2 is connected to the output port of the image display device 200-1. This can be accomplished by pulling up the output DDC communication terminal to a high level via a pull-up resistor. More specifically, the DDC communication processor 207-1

establishes a communication channel between the controller 204-1 and the image display device 200-2 connected to the output port of the image display device 200-1. Thereafter,

5 If an acknowledge signal is received as a response, it is determined that the image display device 200-2 is connected to the output port. Herein, if it is determined that no image display device 200-2 is connected, the process skips to step S105.

10 [0055] If it is determined that the image display device 200-2 is connected, the process proceeds to step S102. In step S102, attribute information of the image display device 200-2, that is, the number of image display devices at downstream locations Chd, the total number of image display devices Cht, the number of pixels in the horizontal direction Nhd, and the number of pixels in the vertical direction Nvd are acquired. In this process, the DDC communication processor 207-1 establishes a communication channel with the image display device 200-2 connected to the output port and acquires the values of the above parameters from the information stored in the memory 206-2 of the image display device 200-2.

15 20 25 [0056] The process then proceeds to step S103. In step S103, the attribute information of the image display device 200-1 is updated. More specifically, the number of image

display devices at downstream locations Cdi is set to Chd + 1, the total number of image display devices Cti is set to Cht + 1, the number of pixels in the horizontal direction Nh is set to Nh + Nhd, and the number of pixels in the vertical direction Nv is set to Nv.

[0057] In the next step S104, in response to a request issued by the controller 204-1, the DDC communication processor 207-1 establishes a communication channel between the controller 204-1 and the memory 206-1, and the controller 204-1 stores updated information, that is, Cti = 2, Cdi = 1, Nh = 1600 (= Nh + Nhd = 800 + 800), and Nv = 600, into the memory 206-1.

[0058] In the next step S105, it is determined whether an image display device is connected to the input port. In this process, in response to a request issued by the controller 204-1, the DDC communication processor 207-1 establishes a communication channel with a device connected to the input port, and it is determined whether an image display device is connected to the input port in a similar manner to the detection of an image display device connected to the output port. However, in this case, it is required that the image display device connected to the input port of the present image display device establish a DDC communication channel with a device connected to its output port. Therefore, it is required that the present image

display device have to issue a DDC communication request to the device connected to the input port of the present image display device. The DDC communication request can be transmitted by means of a communication using an address different from an address defined in the DDC standard. In a case in which a personal computer is connected to the input port, the communication fails, and thus it is determined that no image display device is connected to the input port. In the case it is determined herein that no image display device is connected to the input port, the process is ended without updating any information.

10 [0059] However, if it is determined in step S105 that an image display device is connected to the input port, the process proceeds to step S106. In step S106, information indicating the total number of connected image display devices Ct stored in the memory of the image display device connected to the input port of the present image display device is acquired. The process then proceeds to step S107. In step S107, the total number of image display devices Cti stored in the present image display device 200-1 is compared with the acquired total number of image display devices Ct. If  $Cti \geq Ct$ , the process is ended. However, if  $Ct > Cti$ , the process proceeds to step S108. In step S108, Cti is set such that  $Cti = Ct$ .

25 [0060] In the next step S109, in response to a request

issued by the controller 204-1, the DDC communication processor 207-1 establishes a communication channel between the controller 204-1 and the memory 206-1, and the controller 204-1 stores the updated value of Cti into the memory 206-1. Via the above-described steps S105 to S109, the values of the total number of connected image display devices Cti become equal for all image display devices. Thus, it becomes possible to determine the location of each image display device from the number of image display devices at downstream locations Cdi updated in step S104 and the total number of image display devices Cti.

[0061] The process described above is performed sequentially for each image display device. As a result, for example, in the image display device 200-1 in the system shown in Fig. 1, the attribute information is updated such that the number of pixels in the horizontal direction  $N_h = 1600$ , the number of pixels in the vertical direction  $N_v = 600$ , the number of image display devices at downstream locations  $C_{di} = 1$ , and the total number of image display devices  $C_{ti} = 2$ . Similarly, in the image display device 200-2 connected to the output port of the image display device 200-1, the attribute information is updated such that the number of pixels in the horizontal direction  $N_h = 800$ , the number of pixels in the vertical direction  $N_v = 600$ , the number of image display devices at downstream locations  $C_{di}$

= 0, and the total number of image display devices  $C_{ti} = 2$ .

[0062] Fig. 4 shows the attribute information determined in the above-described manner.

[0063] If a personal computer 100 is connected to the  
5 above-described system including two image display devices,  
the personal computer 100 performs DDC communication with  
the image display device 200-1 at the first stage. From the  
attribute information acquired via this DDC communication,  
the personal computer 100 detects that the image display  
10 device connected to the personal computer 100 has a  
resolution of 1600 in the horizontal direction and 600 in  
the vertical direction. Thus, the personal computer 100  
outputs a signal having an optimum resolution. More  
specifically, the personal computer 100 outputs an image  
15 signal having a resolution corresponding to the display  
resolution of the image display device connected to the  
personal computer 100.

[0064] A process of displaying an image according to the  
first embodiment is described below. Herein, it is assumed  
20 that the system is constructed as shown in Fig. 1 and the  
personal computer 100 outputs an image signal with a  
resolution of 1600 in the horizontal direction and 600 in  
the vertical direction.

[0065] Fig. 5 is a flow chart showing the process of  
25 displaying images on respective image display devices under

the control of the controller 204 of each image display device.

[0066] First, in step S200, the total number of image display devices  $C_{ti}$ , the number of image display device at downstream locations  $C_{di}$ , the intrinsic number of pixels in the horizontal direction  $N_{h0}$ , and the intrinsic number of pixels in the vertical direction  $N_{v0}$  are acquired. In the next step S201, it is determined whether  $C_{ti} > 1$ . If  $C_{ti} = 1$ , there is only one image display device, and thus the present process is terminated. In this case, an image is displayed on the single image display device in a normal manner. However, if  $C_{ti} > 1$ , it is determined that a screen is formed of a plurality of image display devices, and the process proceeds to step S202.

[0067] In step S202, the resolution (the number of pixels in the horizontal direction  $N_{hi}$  and the number of pixels in the vertical direction  $N_{vi}$ ) of the input image signal is detected. The detection of the resolution can be performed by a known method used in a conventional multiscan-type image display device. In the next step S203, the horizontal write length is calculated. Herein, "write" refers to writing into the frame memory 305 shown in Fig. 2. The horizontal write length  $L_h$  can be determined by dividing the number of pixels in the horizontal direction  $N_{hi}$  of the image signal by the total number of image display devices

Cti. This means that the image is equally assigned to all image display devices. In this specific system in which two image display devices are connected to each other, the horizontal write length  $L_h = 800$  obtained by dividing  $N_{hi} = 1600$  by  $C_{ti} = 2$ .

[0068] In the next step S204, the horizontal write start position  $W_{hs}$  is calculated. If the period from a horizontal synchronization signal of the input image signal to an effective image signal is denoted by  $H_{bp}$ , the horizontal write start position  $W_{hs}$  can be given by

$$W_{hs} = H_{bp} + L_h \times (C_{ti} - C_{di} - 1)$$

[0069] In this specific embodiment,  $C_{ti}$  and  $C_{di}$  for the image display device 200-1 at the first stage are  $C_{ti} = 2$  and  $C_{di} = 1$ . Thus, the horizontal write start position  $W_{hs1}$  for the image display device 200-1 at the first stage is given as  $W_{hs1} = H_{bp}$ . For the image display device 200-2 at the second stage,  $C_{ti} = 2$  and  $C_{di} = 0$ , and thus  $W_{hs2} = H_{bp} + 800$ .

[0070] In the next step S205, the horizontal write end position  $W_{he}$  is calculated. The horizontal write end position  $W_{he}$  is determined by adding the horizontal write length  $L_h$  to the horizontal write start position  $W_{hs}$ .

[0071] In the present embodiment, it is assumed that no image display devices are connected in the vertical direction, and thus the vertical write length and the

vertical write start position are not calculated. In the next step S206, the display scaling factors are calculated. The display scaling factors in the horizontal and vertical directions are given by  $M_h = N_{h0}/L_h$  and  $M_v = N_{v0}/N_{vi}$ ,

5 respectively. That is, the display scaling factors are given by the ratios of the numbers of pixels of each image display device to the lengths of the image signal written in the frame memory.

[0072] By storing the write start positions, the write  
10 end positions, and the scale-up/down factors, calculated in the above process, into the respective registers shown in Fig. 2, it becomes possible for each image display device to display the image in a correct manner in accordance with the input image signal.

15 [0073] Fig. 6 shows the manner in which the respective image display devices display the image. In Fig. 6, an area denoted by 200-1 is displayed by the image display device 200-1, and an area denoted by 200-2 is displayed by the image display device 200-2. In the image display device  
20 200-1,  $N_{h0} = 800$ , and thus  $M_h = N_{h0}/L_h = 800/800 = 1$ . Thus, the resolution converter 202-1 directly outputs the image data (with the resolution of  $800 \times 600$ ) stored in the frame memory 305 without scaling up/down the image data.

[0074] Although in the embodiment described above, the  
25 scaling-up/down of the input image signal is performed

independently in the vertical and horizontal directions on the basis of the display area of the screen, the scaling-up/down may be performed by an equal factor in both horizontal and vertical directions so that the aspect ratio of the input image signal is maintained. In this case, the scaling-down factors may be set to be equal to a greater one of scaling-down factors in horizontal and vertical directions which will be employed if they are determined independently, or the scaling-up factors may be set to be equal to a smaller one of scaling-up factors in horizontal and vertical directions which will be employed if they are determined independently.

[0075] As described above, in the present system in which the image display devices are connected to each other such that the image display devices are capable of communicating with each other by means of DDC communication using the DDC communication controller 207, the respective image display devices acquire attribute information of the other image display devices, and the total number of pixels is calculated and stored as EDID information thereby making it possible for the personal computer to regard the connected image display devices as a single high-resolution image display device. In the connected image display devices, each image display device correctly determines which part of the image signal output from the personal computer should be

displayed on the basis of the information about connections among the image display devices.

#### Second Embodiment

5     [0076]     In the first embodiment described above, image display devices are connected in the horizontal direction. In this second embodiment, image display devices are connected in both horizontal and vertical directions.

10    [0077]     Fig. 7 is a block diagram showing constructions of image display devices according to a second embodiment of the present invention. In Fig. 7, similar functional blocks to those in Fig. 1 are denoted by similar reference numerals. The image display devices used herein are similar to those according to the first embodiment except that each image display device additionally includes direction detection means 209. The direction detection means 209 outputs a signal indicating whether an image display device at a following stage is connected in the horizontal direction or in the vertical direction. The direction detection means 209 may be realized, for example, by a mechanical switch capable of being set into either a high or low state. For example, the mechanical switch is set into the high state to indicate that image display devices at following stages are arranged in the horizontal direction or into the low state to indicate that the image display devices at following

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stages are arranged in the vertical direction.

[0078] In the present embodiment, nine image display devices are connected as shown in Fig. 8. Referring to a flow chart shown in Fig. 9, a process of displaying an image according to the second embodiment is described below.

[0079] First, in step S300, attribute information is initialized such that the total number of horizontally connected image display devices  $C_{hti} = 1$ , the number of image display devices at downstream locations in the horizontal direction  $Ch_{di} = 0$ , the total number of vertically connected image display devices  $C_{vti} = 1$ , the number of image display devices at downstream locations in the vertical direction  $Cv_{di} = 0$ , the number of pixels in the horizontal direction  $N_h = N_{h0}$ , and the number of pixels in the vertical direction  $N_v = N_{v0}$ . Herein,  $N_{h0}$  and  $N_{v0}$  denote the numbers of pixels each image display device 200-n has. In this specific embodiment, it is assumed that  $N_{h0} = 800$  and  $N_{v0} = 600$ . In the next step S301, it is determined whether an image display device 200-(n+1) is connected to the output port of the image display device 200-n. Herein, if it is determined that no image display device 200-(n+1) is connected, the process skips to step S307.

[0080] If it is determined that the image display device 200-(n+1) is connected, the process proceeds to step S302 from S301. In step S302, attribute information of the image

display device 200-(n+1), the number of image display devices at downstream locations in the horizontal direction Chd, the total number of horizontally connected image display devices Cht, the number of image display devices at downstream locations in the vertical direction Cvd, the total number of vertically connected image display devices Cvt, the number of pixels in the horizontal direction Nhd, and the number of pixels in the vertical direction Nvd are acquired. In this acquisition process, the DDC

communication processor 207-n establishes a communication channel with the image display device 200-(n+1) connected to the output port and acquires the information stored in the memory 206-(n+1) of the image display device 200-(n+1).

[0081] The process then proceeds to step S303. In step S303, it is determined whether the connected image display device 200-(n+1) is located in horizontal direction or the in the vertical direction. This can be accomplished by examining how the direction detection means 209-n is set.

If it is determined that the connected image display device 200-(n+1) is located in the horizontal direction, the process proceeds to step S304. In step S304, the attribute information of the image display device 200-n is updated.

More specifically, the number of image display devices at downstream locations in the horizontal direction Chdi = Chd + 1, the total number of horizontally connected image

display devices  $C_{hti} = C_{ht} + 1$ , the number of image display devices at downstream locations in the vertical direction  $C_{vd} = C_{vd}$ , the total number of vertically connected image display devices  $C_{vti} = C_{vt}$ , the number of pixels in the horizontal direction  $N_h = N_h + N_{hd}$ , and the number of pixels in the vertical direction  $N_v = N_v$ . Thereafter, the process proceeds to step S306.

[0082] In the case in which it is determined in step S303 that the connected image display device 200-(n+1) is located in the vertical direction, the process proceeds to step S305. In step S305, the attribute information of the image display device 200-n is updated. More specifically, the number of image display devices at downstream locations in the vertical direction  $C_{vdi} = C_{vd} + 1$ , the total number of vertically connected image display devices  $C_{vti} = C_{vt} + 1$ , the number of pixels in the horizontal direction  $N_h = N_h$ , and the number of pixels in the vertical direction  $N_v = N_v + N_{vd}$ . Thereafter, the process proceeds to step S306.

[0083] In step S306, in response to a request issued by the controller 204-n, the DDC communication processor 207-n establishes a communication channel between the controller 204-n and the memory 206-n, and  $C_{hti}$ ,  $C_{hdi}$ ,  $C_{vti}$ ,  $C_{vdi}$ ,  $N_h$ , and  $N_v$  updated in step S304 or S305 are stored into the memory 206-n.

[0084] In the next step S307, it is determined whether an

image display device is connected to the input port. In this process, in response to a request issued by the controller 204-n, the DDC communication processor 207-n establishes a communication channel between the controller  
5 204-n and a device connected to the input port. In the case it is determined herein that no image display device is connected to the input port, the process is ended without updating any information. However, if it is determined that an image display device is connected to the input port, the  
10 process proceeds to step S308. In step S308, the total number of horizontally connected image display devices Cht and the total number of vertically connected image display devices Cvt are acquired from the memory 206-(n-1) of the image display device 200-(n-1) connected to the input port.  
15 The process then proceeds to step S309. In step S309, the total number of horizontally connected image display devices Chti stored in the present image display device 200-n is compared with the acquired total number of horizontally connected image display devices Cht. If Chti = Cht, the  
20 process proceeds to step S311. However, if Cht > Chti, the process proceeds to step S310. In step S310, the value of Chti is replaced by the value of Cht.

[0085] The process then proceeds to step S311. In step S311, the total number of vertically connected image display  
25 devices Cvti stored in the present image display device 200-

n is compared with the acquired total number of vertically connected image display devices Cvt. If  $Cvt_i = Cvt$ , the process proceeds to step S313. However, if  $Cvt > Cvt_i$ , the process proceeds to step S312. In step S312, the value of  
5 Cvt<sub>i</sub> is replaced with the value of Cvt.

[0086] The process then proceeds to step S313. In step S313, in response to a request issued by the controller 204-n, the DDC communication processor 207-n establishes a communication channel between the controller 204-n and the  
10 memory 206-n, and the controller 204-n stores the updated values of Cht<sub>i</sub> and Cvt<sub>i</sub> into the memory 206-n.

[0087] Via the above-described steps S307 to S313, the values of the total number of horizontally connected image display devices Cht<sub>i</sub> and the total number of vertically  
15 connected image display devices Cvt<sub>i</sub> become equal for all image display devices. Thus, it is possible to determine the location of each image display device from the number of image display devices at downstream locations in the horizontal direction Ch<sub>di</sub>, the number of image display  
20 devices at downstream locations in the vertical direction Cv<sub>di</sub>, the total number of horizontally connected image display devices Cht<sub>i</sub>, and the total number of vertically connected image display devices Cvt<sub>i</sub>, which have been updated in step S330.

25 [0088] The process described above is performed

sequentially for each image display device. In the present system in which image display devices each having  $Nh0 = 800$  and  $Nv0 = 600$  are disposed as shown in Fig. 8, the attribute information of, for example, the image display device 200-1 at the first stage is updated in the above process such that the number of pixels in the horizontal direction  $Nh = 2400$ , the number of pixels in the vertical direction  $Nv = 1800$ , the total number of horizontally connected image display devices  $Chti = 3$ , and the total number of vertically connected image display devices  $Cvti = 3$ . The attribute information is shown in Fig. 8 for all image display devices.

[0089] If a personal computer is connected to the above-described system in which image display devices are

connected in the manner shown in Fig. 8, the personal

computer performs DDC communication with the image display device 200-1 at the first stage. From the attribute information acquired via this DDC communication, the personal computer detects that the image display device connected to the personal computer has a resolution of 2400

in the horizontal direction and 1800 in the vertical

direction. Thus, the personal computer outputs a signal having an optimal resolution corresponding to the detected resolution of the image display device. A process of displaying an image is described below. Herein, it is

assumed by way of example that the personal computer outputs

an image signal with a QXGA resolution, that is, a 2048 × 1536 resolution.

[0090] Fig. 10 is a flow chart showing a process of displaying an image according to the second embodiment of the present invention. First, in step S400, the total number of horizontally connected image display devices  $C_{hti}$ , the number of image display devices at downstream locations in the horizontal direction  $Ch_{di}$ , the total number of vertically connected image display devices  $C_{vti}$ , the number of image display devices at downstream locations in the vertical direction  $Cv_{di}$ , the intrinsic number of pixels in the horizontal direction  $N_{h0}$ , and the intrinsic number of pixels in the vertical direction  $N_{v0}$  are acquired. In the next step S401, it is determined whether  $C_{hti} \times C_{vti} > 1$ .

If  $C_{hti} \times C_{vti} = 1$ , there is only one image display device, and thus the present process is terminated. In this case, an image is displayed on the single image display device in a normal manner. However, if  $C_{hti} \times C_{vti} > 1$ , it is determined that a screen is formed of a plurality of image display devices, and the process proceeds to step S402.

[0091] In step S402, the resolution (the number of pixels in the horizontal direction  $N_{hi}$  and the number of pixels in the vertical direction  $N_{vi}$ ) of the input image signal is detected. The detection of the resolution can be performed by a known method used in a conventional multiscan-type

image display device. In the next step S403, the horizontal write length is calculated. Herein, "write" refers to writing into the frame memory 305 shown in Fig. 2. The horizontal write length  $L_h$  can be determined by dividing the number of pixels in the horizontal direction  $N_{hi}$  of the image signal by the total number of horizontally connected image display devices  $C_{hti}$ . In the next step S404, the vertical write length is calculated. The vertical write length  $L_v$  can be determined by dividing the number of pixels in the vertical direction  $N_{vi}$  of the image signal by the total number of vertically connected image display devices  $C_{vti}$ . This means that the image is equally assigned to all image display devices. In the present system in which nine image display devices are connected in such a manner as shown in Fig. 8,  $L_h$  and  $L_v$  are determined as  $L_h = 683$  and  $L_v = 512$  from  $N_{hi} = 2048$ ,  $N_{vi} = 1536$ ,  $C_{hti} = 3$ , and  $C_{vti} = 3$ .

[0092] Thereafter, in step S405, the horizontal write start position  $W_{hs}$  is calculated. If the period from a horizontal synchronization signal of the input image signal to an effective image signal is denoted by  $H_{bp}$ , the horizontal write start position  $W_{hs}$  can be given by

$$W_{hs} = H_{bp} + L_h \times (C_{hti} - C_{hdi} - 1)$$

[0093] For image display devices 200-1, 200-4, and 200-7 at the first stage in the respective horizontal lines,  $W_{hs}$  is given as  $W_{hs1} = H_{bp}$  from  $C_{hti} = 3$  and  $C_{hdi} = 2$ . For

image display devices 200-2, 200-5, and 200-8 at the second stage in the respective horizontal lines, Whs is given as  $Whs2 = Hbp + 683$  from  $Chti = 3$  and  $Chdi = 1$ . For image display devices 200-3, 200-6, and 200-9 at the third stage in the respective horizontal lines, Whs is given as  $Whs3 = Hbp + 1366$  from  $Chti = 3$  and  $Chdi = 0$ .

[0094] In the next step S406, the horizontal write end position Whe is calculated. The horizontal write end position Whe is determined by adding the horizontal write length Lh to the horizontal write start position Whs. That is,  $Whe = Whs + Lh$ .

[0095] In the next step S407, the vertical write start position Wvs is calculated. If the period from a vertical synchronization signal of the input image signal to an effective image signal is denoted by Vbp, the vertical write start position Wvs can be given by

$$Wvs = Vbp + Lv \times (Cvti - Cvdi - 1)$$

[0096] For image display devices 200-1, 200-2, and 200-3 at the first stage in the respective vertical lines, Wvs is given as  $Wvs1 = Vbp$  from  $Cvti = 3$  and  $Cvdi = 2$ . For image display devices 200-4, 200-5, and 200-6 at the second stage in the respective vertical lines, Wvs is given as  $Wvs1 = Vbp + 512$  from  $Cvti = 3$  and  $Cvdi = 1$ . For image display devices 200-7, 200-8, and 200-9 at the third stage in the respective vertical lines, Wvs is given as  $Wvs2 = Vbp + 1024$  from  $Cvti$

= 3 and  $Cvdi = 0$ .

[0097] In the next step S408, the vertical write end position  $Wve$  is calculated. The vertical write end position  $Wve$  is determined by adding the vertical write length  $Lv$  to the vertical write start position  $Wvs$ .

[0098] Thereafter, the process proceeds to step S409. In step S409, the display scaling factors are calculated. The display scaling factors in the horizontal and vertical directions are given by  $Mh = Nh0/Lh$  and  $Mv = Nv0/Lv$ ,

respectively. That is, the display scaling factors are given by the ratios of the numbers of pixels of each image display device to the lengths of the image signal written in the frame memory. In the present example,  $Mh = 800/683 = 1.17$ , and  $Mv = 600/512 = 1.17$ . Fig. 11 shows the attribute information determined in the above-described manner.

[0099] Although in the embodiment described above, the scaling-up/down of the input image signal is performed independently in the vertical and horizontal directions on the basis of the display area of the screen, the scaling-up/down may be performed by an equal factor in both horizontal and vertical directions so that the aspect ratio of the input image signal is maintained. In this case, the scaling-down factors may be set to the greater of the scaling-down factors in the horizontal and vertical directions which will be employed if they are determined

independently, or the scaling-up factors may be set to the smaller of the scaling-up factors in horizontal and vertical directions which will be employed if they are determined independently.

5     **[0100]**     As described above, in the present system in which the image display devices are connected to each other such that the image display devices are capable of communicating with each other by means of DDC communication using the DDC communication controller 207, the respective image display  
10    devices acquire attribute information of the other image display devices, and the total number of pixels is calculated and stored as EDID information thereby making it possible for the personal computer to regard the connected  
15    image display devices as a single high-resolution image display device. In the connected image display devices, each image display device correctly determines which part of the image signal output from the personal computer should be displayed on the basis of the information about connections among the image display devices.

20    **[0101]**     Although in the embodiments described above, each image display device acquires Chti, Chdi, Cvti, and Cvdi by communicating with adjacent image display devices located at preceding and following stages, Chti, Chdi, Cvti, and Cvdi may be set by a user by setting a switch or the like  
25    provided in each image display device. In this case, the

resolution can be determined by performing a simple calculation of the cumulative sum via the DDC communication.

[0102] As described above, the present invention makes it possible to realize a multidisplay system at low cost using image display devices which may also be used as standalone image display devices.

[0103] Furthermore, the present invention makes it possible to realize a multidisplay system having a plurality of image display devices without an additional controller for controlling the display operation.

[0104] While the present invention has been described with reference to what are presently considered to be the preferred embodiments, it is to be understood that the invention is not limited to the disclosed embodiments. On the contrary, the invention is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.